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ALLOCATING AIR FORCE CAREER FIELD ACCESSION TARGETS: AN OPTIMIZATION BASED TOOL

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The USAF officer accession sources annually produce three thousand non-rated line officers who must be classified into career fields. Under the current system, many career field accession goals are not met. This mismatch occurs primarily because of unreasonable targets set for the various commissioning sources. This thesis presents an optimization-based target allocation tool that mitigates the existing mismatch between long-term manpower needs and near-term accession source outputs. This Java-based application enables users to weight multiple objectives, set priorities for filling various career fields, solve for optimal targets, and then explore results, presented in the form of interactive tables and charts. Within a friendly graphical user interface, users determine practical targets with ease by interactively adjusting the optimality criteria and fill priorities and then reviewing the resulting classifications. These new targets will vastly improve the ability of the USAF to meet accession needs, exploit the unique skills of its officers, and satisfy officer preferences. This means that officer recruiting dollars will be better utilized as long-term manpower needs are better met. Additionally, job performance and retention are likely to improve as more career fields are filled with highly qualified officers and officers are more frequently placed into their desired career fields.

ABSTRACT

The USAF officer accession sources annually produce three thousand non-rated line officers who must be classified into career fields. Under the current system, many career field accession goals are not met. This mismatch occurs primarily because of unreasonable targets set for the various commissioning sources. This thesis presents an optimization-based target allocation tool that mitigates the existing mismatch between long-term manpower needs and near-term accession source outputs. This Java-based application enables users to weight multiple objectives, set priorities for filling various career fields, solve for optimal targets, and then explore results, presented in the form of interactive tables and charts. Within a friendly graphical user interface, users determine practical targets with ease by interactively adjusting the optimality criteria and fill priorities and then reviewing the resulting classifications. These new targets will vastly improve the ability of the USAF to meet accession needs, exploit the unique skills of its officers, and satisfy officer preferences. This means that officer recruiting dollars will be better utilized as long-term manpower needs are better met. Additionally, job performance and retention are likely to improve as more career fields are filled with highly qualified officers and officers are more frequently placed into their desired career fields.

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LIST OF ACRONYMS

AFB	Air Force Base
AFIT	Air Force Institute of Technology
AFPC	Air Force Personnel Center
AFPOA	Air Force Personnel Operations Agency
AFSC	Air Force Specialty Code
DPSAA	Directorate of Personnel Studies and Analysis Agency
OTS	Officer Training School
NPS	Naval Postgraduate School
NRL	Non-Rated Line
NRLOAC	Non-Rated Line Officer Accession Conference
ROTC	Reserve Officer Training Corps
TALENT	Target Allocation and Exploratory Network Tool
USAF	United States Air Force
USAFA	United States Air Force Academy

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EXECUTIVE SUMMARY

The Air Force annually places newly commissioned officers into career fields. This process has implications for the long-term effectiveness of the service as the Air Force, like other services, must grow its own talent. In this environment, properly utilizing available talent is important.

There are two types of Air Force career fields: rated and non-rated. Rated officers are pilots and other commissioned air crew members. The classification of those officers is relatively simple. Non-rated line officers do not have aeronautical ratings and carry out non-rated operations and mission support. Non-rated line officers and the nearly forty specialties they fill are the focus of this thesis. Annual Air Force requirements are set for the number of officers in each non-rated line career field. Each year, at an accessions conference, the three commissioning sources meet to divide the requirements and set individual classification targets, which are numbers of officers in each field that will be filled by each accession source. This problem is complicated because not every graduate is qualified for every career field. The need to place individuals into those career fields that they desire and for which they are highly qualified further complicates the problem.

The current method of setting targets for non-rated line officer classification is inefficient and produces substandard results. The accessions conference tends to turn into a battle over "easy-to-fill" career fields at the expense of "hard-to-fill" fields. That is, the commissioning sources fight for more slots in the popular career fields for which the supply of qualified officers is plentiful. In contrast, the commissioning sources seek to give away slots in the less popular career fields and in those career fields for which the supply of qualified officers is limited. A few years ago, rather than engage in the power struggle, one commissioning source decided not to attend the conference. Instead, they left their targets as-is with the knowledge that they would not be able to meet them. Clearly, a conference whose success depends on the cooperative ability of the sources will not produce the desired results under these circumstances. Yet, even if the commissioning sources can be convinced to cooperate, it is unlikely that they will be able

to resolve all of the problems by simply trading slots back and forth across a table during the course of one weekend. The problem is much too large to be solved in this manner. If the current process continues to be used, the commissioning sources will classify their students with poor targets.

The Target Allocation and Exploratory Network Tool (TALENT), presented in this thesis, is an interactive optimization-based tool that improves the target setting process. It considers the educational background and the preferences of students from each commissioning source, along with the requirements of each career field. This tool addresses multiple objectives and enables the user to set the weights for relative importance of these objectives. The graphical user interface enables users to conduct "what-if" analysis by allowing rapid solution for different weighting schemes, and generating useful graphical representations of the solutions.

The underlying model is an application of network theory, with cascading shortage and surplus pools. The penalty for the first ten officers short for a career field, say, might be 1 unit, while the penalty for the next ten officers might be 2 units. This is represented by two shortage arcs in the network, each with a capacity for ten officers, and a cost of 1 or 2 units, respectively. The lowest cost arcs are saturated first, and then the additional shortfalls cascade through the next cheapest arc. The underlying problems solve very quickly and the interface allows it to be used by individuals with no technical background. It is implemented in Java so that no proprietary software is needed to run it.

TALENT makes the accession capabilities of the commissioning sources more transparent and, due to its fast runtime, facilitates rapid, thorough analyses of alternatives. Rather than squabbling over politics, the commissioning sources can focus on the important issues, those being the costs of missing overall Air Force goals and choosing appropriate weights for each objective. By using TALENT, at the end of the accessions conference, generally accepted and feasible accession targets can be developed. These targets will set the commissioning sources up for success, as defined by the objectives, when it comes time for classification, as they will have attainable targets and, hence, will be able to focus on meeting the desires of their students.

Many military leaders claim that winning the war for talent is the key issue for the long term health of the services. This model is a major weapon that can help win the war for talent by making the best use of it.

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I. INTRODUCTION

A. BACKGROUND

1. Air Force Specialty Codes

The Air Force cannot carry out aerospace operations without a strong support structure on the ground. For this reason, Air Force officers perform many different jobs. Jobs that require common qualifications are called specialties. Each specialty is identified by a four or five digit alphanumeric code, referred to as an Air Force specialty code (AFSC). At the time of commissioning, every officer is assigned an AFSC. This AFSC will specify what types of positions, or billets, an officer may fill during his career.

Some specialties require officers to possess a specific degree. For example, a weather officer must have a degree in meteorology or a similar field. These specialties are generally technical career fields in engineering and the sciences. Often, these degree requirements make it difficult to meet the manpower needs of these AFSCs. The vast majority of specialties do not have degree requirements. AFSCs denoting these career fields can be assigned to any commissioned officer. Since any officer is eligible to enter these specialties, it is relatively easy to meet their manpower needs.

2. Non-Rated Line Officers

There are two kinds of commissioned officers: line and non-line. Non-line officers are non-combat specialists who do not command troops. This includes those officers in the medical specialties as well as those in the professional specialties (e.g. lawyers and chaplains). Line officers constitute the bulk of the officer corps and provide management and leadership in their area of responsibility. Line officers are divided into two categories: rated and non-rated. Rated line officers have aeronautical ratings and are directly involved in flying operations (e.g. pilots and navigators). Non-rated line officers do not have aeronautical ratings and carry out non-rated operations and mission support. Non-rated line officers and the nearly forty specialties they fill are the focus of this study.

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3.   Commissioning Sources

The three sources of commissioning for non-rated line officers (NRL) are the Officer Training School, the Reserve Officer Training Corps, and the United States Air Force Academy. Annually, OTS commissions approximately 1,400 NRL officers, ROTC provides the Air Force with roughly 1,700 NRL officers, and USAFA is the source of nearly 400 NRL officers.

Officer Training School (OTS) is located at Maxwell AFB, AL and is available to graduates from accredited colleges and universities. Admission to OTS is competitive and based on the individual's desires, qualifications, and specific Air Force manpower needs. OTS students already possess a college degree when they enter into the program. Thus, they need only attend a twelve week program prior to being commissioned as an officer. Non-rated line officers commissioned through OTS incur a four-year active duty service commitment.

The Air Force Reserve Officer Training Corps (ROTC) program is available at colleges and universities nationwide. ROTC students attend college and take part in military activities aimed to prepare them for life as an officer. Most ROTC students receive scholarships that range anywhere from one to four years in duration. For the most part, full scholarships are offered to students in the most critically demanded technical majors, with partial scholarships offered to students in the less demanded technical and non-technical majors. Once students accept a scholarship, they are usually not free to change their academic major unless it is in the best interest of the Air Force. Non-rated line officers commissioned through ROTC incur a four year active duty service commitment.

The United States Air Force Academy (USAFA) in Colorado Springs, CO offers students a four year education completely free of charge. In addition to academics, USAFA students take part in numerous military, athletic, and leadership activities year round. Students are free to choose from among thirty academic majors offered at USAFA. Non-rated line officers commissioned through USAFA incur a five year active duty service commitment.

B.   NON-RATED LINE OFFICER CLASSIFICATION

1.   Distributing Initial AFSC Accession Targets

The analysis section of the Air Force Personnel Operations Agency (AFPOA) in Washington, D.C. is responsible for determining the annual accession goals for non-rated line officer AFSCs. These accession goals represent the number of newly commissioned officers that should enter into each specialty in a given year in order to meet the manpower needs of the Air Force. In setting these goals, AFPOA analysts need to balance two considerations. First, the number of Second Lieutenant vacancies in each specialty must be considered. Vacancies result when existing Second Lieutenants are promoted and move on to advanced jobs within the specialty. The second consideration in determining accession goals is the future demand for middle and senior grade officers in each AFSC. By analyzing historical officer attrition behavior, the analysts determine how many officers to commission into each non-rated line officer specialty so that after projected officer losses, there will still be a sufficient number of officers by grade remaining in each specialty.

Students within each commissioning source are classified independently of the other commissioning sources. Once overall Air Force accession goals have been determined, they are split among the three commissioning sources, so that each source is assigned an accession target, or quota, for each AFSC. There are two ways that this has been done in the past. Recently, there was a model that considered the historical ability of each commissioning source to produce officers eligible for certain AFSCs in splitting up the targets. For example, if ROTC tended to produce a higher percentage of engineers than the other two sources, ROTC was given a higher percentage of the overall accession goal for the engineering AFSCs. That strategy was abandoned in favor of the simpler "fair-share" strategy. This strategy assigns a target to each commissioning source based on the percent of total accessions that it produces[1]. For example, if OTS is expected to produce 1,400 of the 3,500 non-rated line officers accessed in a given year, they will be given targets that represent 40% of the annual accession goal for each AFSC.

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[1] Jeremy Sherette is an AFPOA analyst who works closely with the model used for determining accession goals and allocating them to the commissioning sources. This discussion is based on email correspondence and presentation notes provided by him on 9 December 2002.

The annual accession goals derived from the AFPOA model are largely based on a long-term perspective and as a result tend to be very optimistic. It is generally the case that the current distribution of students within the commissioning sources is not considered, or perhaps is not given very much weight, in the AFPOA model. That is to say, the accession goal for a specific AFSC may exceed the total number of students who actually possess the degree that is required for classification into that specialty. There is no reason to expect that the students graduating from each of the commissioning sources will have similar educational backgrounds. Hence, when the overall accession goals are split among the commissioning sources in a "fair-share" manner, this problem is likely to be magnified. There is certainly no guarantee that each commissioning source will be able to produce its "fair-share" of the officers for every AFSC. This mismatch between the long-term needs of the Air Force and the near-term accession capabilities of the three accession sources, coupled with the naïve method by which accession goals are partitioned between the three commissioning sources, causes many unnecessarily large deviations from the accession goals proposed by AFPOA.

2. The Non-Rated Line Officer Accessions Conference

Each year, the Air Force Personnel Operations Agency holds the Non-Rated Line Officer Accessions Conference (NRLOAC). Here, representatives from each accession source present their likely accession figures and attempt to resolve target problems by trading AFSC slots with each other. For example, if ROTC thinks that it will have trouble meeting a target in a given AFSC, they might trade two of the slots they have been assigned in this AFSC to USAFA in exchange for two slots in an AFSC for which they have plenty of qualified officers.

Naturally, the commissioning sources are motivated to acquire feasible targets. Each commissioning source exists in order to produce officers to satisfy the manpower needs of the Air Force. Thus, meeting its quota is one way that each commissioning source can validate its existence. While specialties that don't require officers to possess specific degrees tend to be relatively easy to fill, targets for those AFSCs that have degree requirements are always more difficult to meet. As a result, each representative tends to

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argue in favor of more slots in the "easy-to-fill" specialties, while hoping to decrease their allocated slots in the "hard-to-fill" specialties[2].

The commissioning sources are also motivated to satisfy the personal desires of their students. When student desires are satisfied, it increases the likelihood that they will be productive in their work and make the Air Force a career. It also seems to be the case that commissioning sources are contacted by senior leaders (e.g. congressmen and flag officers) when their students are placed into low preference career fields. So, in addition to arguing for "easy-to-fill" specialties, the commissioning sources also fight for the more desirable specialties as well.

3.   Conducting Non-Rated Line Officer Classification

The Directorate of Personnel Studies and Analysis (DPSAA) located at the Air Force Personnel Center (AFPC) in San Antonio, TX coordinates the classification of non-rated line officers from all three accession sources into specialties. The students from a given commissioning source are classified independently of the students from the other two sources using the accession goals provided by AFPOA.

The Officer Training School graduates eight classes of officers annually. Thus, officers commissioned through OTS are classified during one of eight classification cycles. Students graduate from the Reserve Officer Training Corp program throughout the year. However, the vast majority of students graduate in either the fall or the spring. As such, there are two classification cycles for officers commissioned through ROTC. The main cycle, which is by far the larger of the two cycles, takes place in November. It includes all of the students who will be commissioned in the spring or summer. The off cycle takes place in February for the students who will graduate during the fall or winter months. The overwhelming majority of officers commissioned through the United States Air Force Academy graduate during the spring. Only a handful of students graduate late in the winter. Thus, the USAFA students are classified during one cycle that occurs in the fall.

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2 William Plies is an economics professor at the USAF Academy and previously worked closely with the AFPOA model and the classification process. This discussion is based on an email sent from him to Andrew Armacost, another professor at the USAF Academy, on 11 November 2002.

C.   THE OBJECTIVES OF THE CLASSIFICATION PROCESS

1.   Meeting AFSC Manpower Needs

Each specialty contributes to the overall mission of the Air Force in its own unique way. Thus, it is important that each specialty has enough officers to perform everyday operations. The annual accession targets proposed by AFPOA represent a forecast of these requirements. When the number of officers classified into a given AFSC falls short of the accession goal, there will be a near-term junior officer shortage in the career field. Depending on how the Air Force responds to this near-term shortage, it may also lead to a long-term senior officer shortage as well. Shortages are costly to the Air Force. A small shortage may be overcome by asking a few people to work overtime or by cross-training, but a large shortage may seriously impact mission effectiveness. Exceeding the AFSC accession targets can also be very costly. Recruiting and producing officers is expensive and the budget to do so is limited. The Air Force cannot afford to commission unneeded officers.

2.   Meeting AFSC Quality Needs

Certain skills are scarce and at the same time highly demanded within certain career fields. An officer who has these skills should be utilized accordingly. Many specialties accept officers regardless of their degree. However, these fields may prefer to have certain officers over others. For example, a student possessing a bachelor's degree in any academic field can become a Public Affairs officer. However, a student with a strong background in mass communication or public relations would be expected to perform better than, say, a student with a degree in architecture. Similarly, students with formal training in a foreign language may be preferred over students without this training in the intelligence career field.

3.   Meeting Personal Preferences

Recruiting and training individuals to be commissioned as Air Force officers is an expensive undertaking. The military enjoys a unique benefit in that officers incur an

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initial commitment, in the case of non-rated line officers, of four or five years. However, failure to retain officers past this point can be very costly as well. With this in mind, job performance and retention are paramount. Clearly, many factors contribute to job satisfaction and good and bad jobs exist within every specialty. So, it would be naive to assume that job satisfaction is an absolute result of the degree by which an individual's career field desires have been met. However, it is reasonable to assume that officers are more likely to perform better and be more satisfied in a preferred specialty. Therefore, it is sensible to meet student preferences whenever it is possible to do so.

D. PROBLEM STATEMENT

By distributing "fair-share" targets to the commissioning sources, the individual accession capability of each source is ignored. As a result, the target for a specific AFSC that is assigned to a particular commissioning source may exceed the number of students within the source who actually possess the degree that is required for classification into that specialty. These targets also fail to consider the special qualifications and the personal preferences of students within each source. The agencies involved recognize this flaw and realize that its effects can be very costly to the mission capability of each specialty and seek to address this problem at the Non-Rated Line Officer Accessions Conference.

This conference is seldom effective, however. Instead, it is notorious for turning into a battle over "easy-to-fill" career fields at the expense of "hard-to-fill" fields. That is, the commissioning sources fight for more slots in the popular career fields for which the supply of qualified officers is plentiful while trying very hard to give away slots in the less popular career fields and in those career fields for which the supply of qualified officers is limited. A few years ago, rather than engage in the power struggle, one commissioning source decided not to attend the conference. Instead, they left their targets as-is with the knowledge that they would not be able to meet them[3]. Clearly, a conference whose success depends on the cooperative ability of the sources will not produce the desired results under these circumstances.

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[3] Ibid.

Even if the sources can be coaxed into cooperating, it is unlikely that the problem will be sufficiently resolved. Dividing the overall goal for each AFSC among three different commissioning sources and multiple cycles is not a simple task. A problem of this magnitude cannot be suitably resolved at a conference by simply trading slots back and forth across a table. Regardless of how much time and effort is spent doing this, there is no way to guarantee that these targets will be representative of the accession capabilities of each source. That is, there will likely be slots that one source cannot fill that another source would be able to fill if the need were communicated.

The current method of setting targets for non-rated line officer classification is inefficient and produces substandard results. If the current process continues to be used, the commissioning sources will be forced to classify their students with second-rate targets. As a result, the classification process will not satisfactorily accomplish its objectives. Costly short and long-term shortages and surpluses will result in many AFSCs and the unique and valuable skills that many officers possess will not be sufficiently utilized.

This research focuses on the creation of an optimization-based tool that will alleviate the mismatch between the long-term manpower needs of the non-rated line officer specialties and the near-term accession capabilities of the three commissioning sources. The Target Allocation and Exploratory Network Tool (TALENT) consists of two parts: an optimization model and a graphical user interface. An efficient optimization model is important so that the underlying problem can be solved quickly. The graphical user interface will allow personnel analysts, who may not be well-versed in operations research, to manipulate this model to explore a wide range of possible solutions. TALENT will improve the ability of personnel analysts to set realistic, attainable, optimal targets for non-rated line officer classification.

II. THE OPTIMIZATION MODEL

The approach is to set targets by modeling the classification of officers as a flow, in a certain network, of available non-rated line officers to AFSCs. This network structure allows the use of a special-purpose algorithm to rapidly solve the problem. This algorithm eliminates the need for traditional integer and linear programming solvers, and hence, no proprietary software is required.

A. MODEL FORMULATION

1. Index Use

The target setting problem is formulated as a minimum cost flow problem in a directed network $G = (N, A)$. Every node $i \in N$ is an element of one of the following sets, with two exceptions. The node $esp \in N$ (extra student pool) receives flow from surplus nodes $o \in O$ and sends flow to the shortage nodes $u \in U$ [4]. The dummy node $sink \in N$ accepts flow from each $c \in C$. The following indices are used to describe nodes within the target setting model.

$s \in S$ student awaiting classification $S = \{student_1, ..., student_s\}$

$c \in C$ non-rated line officer specialty code $C = \{13BX, 13MX, ..., 71SX\}$

$u \in U$ shortage of level u $U = \{short_1, short_2, ..., short_u\}$

$o \in O$ surplus of level o $O = \{surp_1, surp_2, ..., surp_o\}$

The goal is to assign targets for each AFSC, for each classification cycle, to the three commissioning sources. To extract this information the following indices are used.

$soc \in SOC$ source of commissioning $SOC = \{OTS, ROTC, USAFA\}$

$t \in T$ classification cycle $T = \{1, 2, ..., 8\}$

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[4] When the accession goal for a particular AFSC is exceeded, flow is routed from that AFSC to a shortage node. The flow is then sent through the extra student pool to a shortage node. Finally, the flow is routed from the shortage node to an AFSC, to help that AFSC meet its accession goal.

2. Data and Parameters

Every node is labeled with an initial supply or demand and every arc is assigned a cost and a capacity. These numerical values are determined by previously collected data and by parameters set by the decision maker. The minimum cost flow problem seeks to minimize only one objective: the total cost of the flow through the network. The target setting problem, however, has three objectives. The relative weight of each objective is set by the decision maker and this determines the contribution of each objective towards the overall cost of the flow through the network. The per-unit penalties assessed to shortages and surpluses are modeled as step functions that increase as the level, or magnitude, of the shortage or surplus increases. Once again, these penalties are defined by the decision maker. The following data and parameters appear in the network used to model the target setting problem.

$$qual_{sc} = \begin{cases} 1, & \text{if student } s \text{ is qualified for Air Force specialty code } c \\ 0, & \text{otherwise} \end{cases}$$

$$hqual_{sc} = \begin{cases} 1, & \text{if student } s \text{ is highly qualified for Air Force specialty code } c \\ 0, & \text{otherwise} \end{cases}$$

$desire_{sc}$ the desire expressed by student s to be classified into Air Force specialty code c (note: this is used to define a cost in a minimum cost flow problem and hence is small when the student's desire is large)

$goal_c$ the overall accession goal for Air Force specialty code c

$shortpen_{cu}$ the per-unit penalty incurred for falling short of the accession goal set for Air Force specialty code c when the shortage is currently at level u

$surppen_{co}$ the per-unit penalty incurred for exceeding the accession goal set for Air Force specialty code c when the surplus is currently at level o

$shortlim_{cu}$ the number of students that can be charged $shortpen_{cu}$ (i.e. the number of students that are included in a shortage of level u)

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$surplim_{co}$ the number of students that can be charged $surppen_{co}$ (i.e. the

number of students that are included in a surplus of level o)

w_m the weight applied to the manpower needs objective

w_q the weight applied to the quality needs objective

w_d the weight applied to the objective to meet student desires

To extract targets from the solution, there is a need to identify the commissioning source and the classification cycle of each student. While not represented in the actual network, it is necessary to define the following data.

$source_s$ the source of commissioning of student s $source_s \in SOC$

$cycle_s$ the cycle to which student s belongs $cycle_s \in T$

3.   Variables

The decision variables represent flow across arcs in the directed network. They are defined as follows.

X_{ij} the flow across the arc $(i, j) \in A$

While not used in computing a solution to the target setting problem, the following auxiliary variables are of interest to the decision maker.

$target_{c,soc,t}$ number of students commissioning source soc is required to classify

into AFSC c during cycle t

$shortage_c$ number of students by which the sum of all targets AFSC c falls short

of the accession goal for AFSC c

$surplus_c$ number of students by which the sum of all targets for AFSC c

exceeds the accession goal for AFSC c

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4. The Minimum Cost Flow Model

This problem as modeled as a minimum cost flow problem[5], a problem that arises in almost all industries and is very useful in solving large combinatorial optimization problems. The objective of the minimum cost flow problem is to determine the least costly manner by which to ship a commodity through a network so as to utilize the supply or meet demand of every node.

The classification of students is modeled as a flow in a directed network $G = (N, A)$ with a cost c_{ij} and a capacity u_{ij} associated with each arc $(i, j) \in A$ and a supply/demand $b(i)$ associated with each node $i \in N$. The minimum cost flow formulation of this problem has the following linear programming interpretation:

$$\text{Minimize} \quad \sum_{(i,j) \in A} c_{ij} X_{ij} \quad (2.1)$$

$$\text{subject to} \quad \sum_{\{j:(i,j) \in A\}} X_{ij} - \sum_{\{j:(j,i) \in A\}} X_{ji} = b(i) \quad \text{for all } i \in N \quad (2.2)$$

$$0 \leq X_{ij} \leq u_{ij} \quad \text{for all } (i,j) \in A \quad (2.3)$$

where

$$target_{c,soc,t} = \sum_{\{s:source_s = soc, cycle_s = t\}} X_{sc} \quad \text{for all } c \in C, soc \in SOC, t \in T \quad (2.4)$$

The objective function in (2.1) represents the total cost of the implied assignments[6]. The mass-balance constraints are represented in (2.2). The first term in the equation represents the total flow out of node i and the second term represents the total flow into the node. The net flow out of the node is the difference between the first and second term. The net flow out of supply nodes is positive and the net flow out of demand nodes is negative. The constraints in (2.3) ensure nonnegative flow across each arc and enforce the arc capacities. The auxiliary variable, $target_{c,soc,t}$, the variable of interest to decision makers, is defined in (2.4).

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5 The is the fundamental problem addressed in *Network Flows*, by Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin (Upper Saddle River: Prentice Hall, 1993)

6 This is the implicit value of the solution, in terms of the classification objectives, given that targets are used in classification. The actual numerical value of a particular solution depends on the weights assigned to each objective and the shortage/surplus costs specified by the decision maker.

B. NETWORK VISUALIZATION

In this section, the network used to model the target setting problem is described in detail. First, a simple network is presented. The shortcomings of this network are explained and the network is improved to provide an elastic minimum cost flow formulation of the target setting problem that can be efficiently solved with a special-purpose algorithm.

Assume, for the time being, that the annual accession goal for each Air Force specialty code must be met with equality. Let S be the set of all students that will be classified this year and let C be the set of all non-rated line officer specialty codes into which they can be classified. Consider the directed network $G = (N, A)$ shown below, where $N = S \cup C$ and $A = \{(s,c) : s \in S, c \in C\}$. As is customary, every node $i \in N$ is labeled with a supply or demand $b(i)$ and each arc $(i, j) \in A$ is labeled with a cost c_{ij} and a capacity u_{ij}.
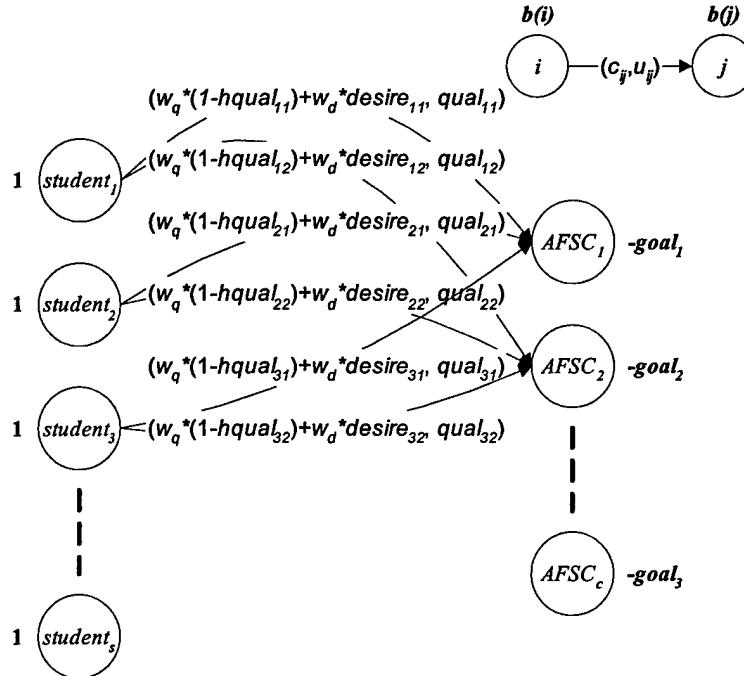

Figure 1. Directed network with students and specialty codes

Every student needs to be classified into exactly one AFSC prior to commissioning. In a minimum cost flow problem, all supply within the network must be

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consumed. Thus, by assigning a supply of one to each student $s \in S$, any feasible solution is guaranteed to classify every student into exactly one AFSC. That is, there will be a nonzero flow on exactly one arc incident to each student. Similarly, each Air Force specialty code $c \in C$ is assigned a demand equal to $goal_c$, which represents the overall accession goal for that AFSC. Many AFSCs have degree entry requirements. That is, students may be required to possess a specific degree in order to be classified into a given AFSC. To enforce the degree requirements, the capacity of each arc $(s,c) \in A$ is set to $qual_{sc}$, which equals one if student s possesses the degree required for entry into AFSC c and zero otherwise. Thus, the supply at a given student node can only be routed along arcs to AFSCs for which the student is qualified.

Assuming that the overall accession goal for each AFSC is met exactly, the minimum cost flow problem has two objectives: assigning students to those AFSCs for which they are highly qualified and satisfying the personal desires of the students being classified. Let w_q and w_d be the weights given to quality needs and personal desires, respectively. In Figure 1, $hqual_{sc}$ equals one if student s is highly qualified for AFSC c, and zero otherwise. Hence, the quantity $1 - hqual_{sc}$ is an obvious choice to penalize flow across arcs that constitute the classification of a student into an AFSC for which he is not highly qualified. In this network, $desire_{sc}$ is a number that is small when student s wishes to be classified into AFSC c and large when this is not the case. With the two objectives in mind, the cost c_{ij} of assigning student s to AFSC c is defined as the weighted sum $w_q(1 - hqual_{sc}) + w_d desire_{sc}$.

At this point, it is prudent to allow for the possibility that all accession goals cannot be met with equality. While it is desirable for students to be classified in this manner, there is certainly no guarantee that this is possible. When no feasible solution exists, this model is of no help to decision makers (other than alerting them of the fact that the accession goals are unrealistic). When no solution exists that exactly meets the overall accession goals, it is necessary for the decision makers to find a solution that is, in one way or another, close to meeting the overall AFSC accession goals for the given year. A more useful network flow model is obtained by modifying the previous network.

Consider the directed network $G = (N, A)$, shown in Figure 2. In this network, N includes all nodes in the sets S and C with two additional nodes: a shortage node and a surplus node. There is one arc from each AFSC to the surplus node and one arc from the shortage node to each AFSC. Additionally, there is a directed arc from the surplus node to the shortage node, as a surplus in one AFSC undoubtedly implies a shortage in another, and vice versa.
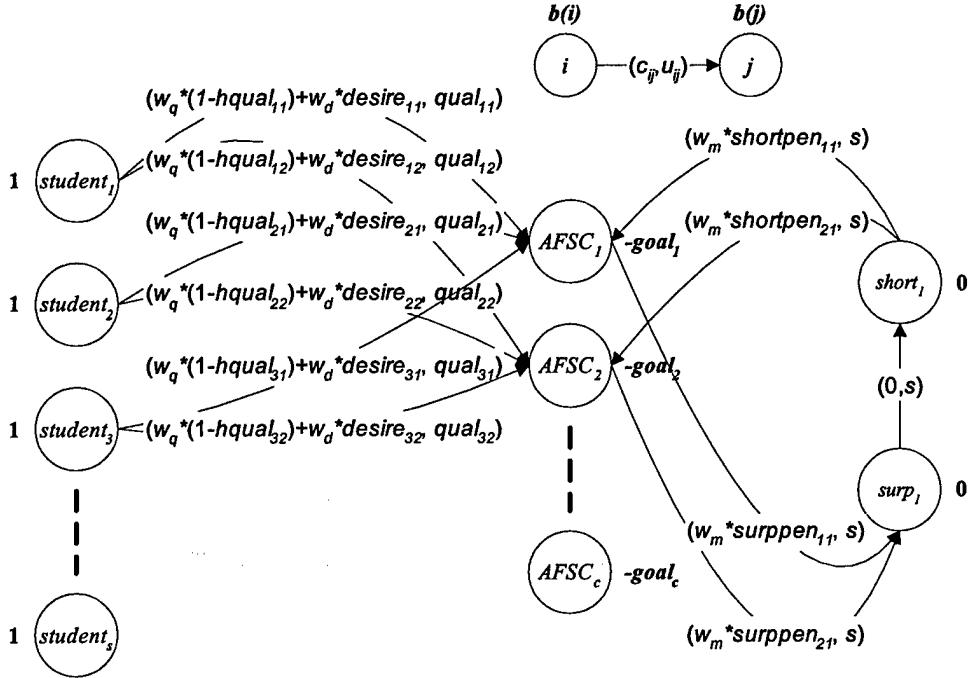
Figure 2.   Four student and two AFSC network with shortage and surplus nodes

In this model, the sum of all the AFSC accession goals is equal to the total number of students in the model. Thus, when one AFSC falls short of its overall accession goal, another AFSC will be required to exceed its goal. When this occurs, the surplus and shortage nodes redistribute supply from the AFSCs with surplus officers to the AFSCs that are short of their accession goals. The surplus and shortage nodes ensure that the demand at every AFSC node will be completely satisfied, even when it is not possible to meet the accession goals of every AFSC. Note that, while the arcs incident to the shortage and surplus nodes serve to redistribute the supply sent from the student nodes, the flow across the student-to-AFSC arcs represent the actual student classifications. That is, the unit of supply sent from student s may be routed out of AFSC

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c and into another AFSC through the surplus and shortage nodes. However, this does not change the fact that student s is classified into AFSC c[7].

Deviations from the stated accession goals are undesirable. To model this, nonzero costs are assigned to the arcs into the surplus node and the arcs out of the shortage node. Let $surppen_{c1}$ represent the penalty assigned to a surplus in AFSC c and let $shortpen_{c1}$ be the penalty assigned to a shortage in AFSC c. Then, by setting the cost of every AFSC-to-surplus arc, equal to $surppen_{c1}$ and the cost of every shortage-to-AFSC arc equal to $shortpen_{c1}$, deviations from the stated accession goals are penalized as desired. Moreover, these penalties can be intelligently set so as to enforce a desired fill priority for the AFSCs. That is, severely overmanned AFSCs are assigned the largest surplus costs and smallest shortage costs. The opposite is true for those AFSCs that are largely undermanned in the higher ranks. The deviational costs are weighted by w_m in a similar fashion to before, where w_m represents the relative weight assigned to the objective of meeting the manpower needs of the non-rated line officer AFSCs.
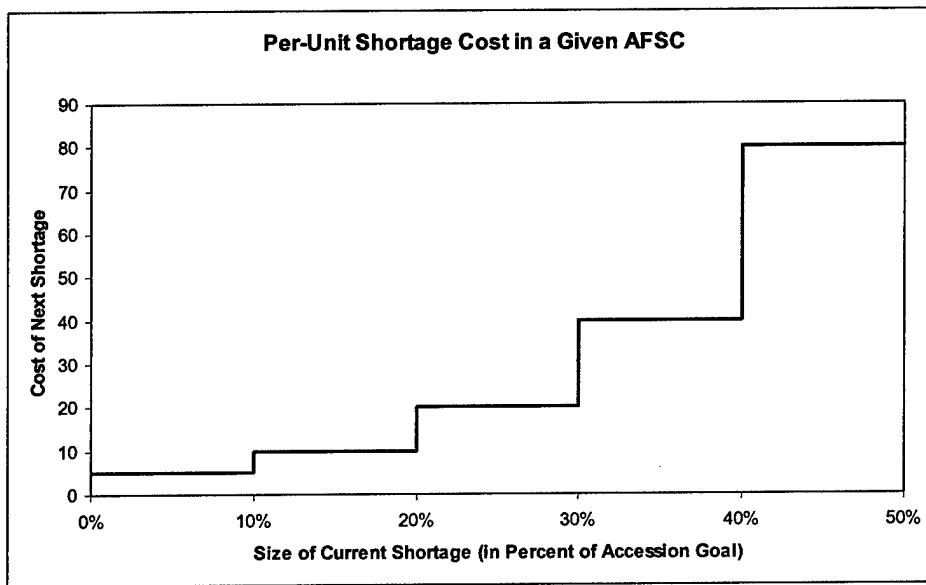
Figure 3.   A step function that models the non-linear nature of shortage costs

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7 Flow across a student-to-AFSC arc represents a classification. Flow across the arc (s, a) indicates that student s is classified into AFSC a. As a result, the target for AFSC a allocated to that student's commissioning source and cycle increases by one.

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It is generally the case that the marginal cost of a shortage increases along with the magnitude of the shortage. For example, a career field may be able to recover from a small shortage by asking a few people to occasionally work overtime or in a different capacity. However, a large shortage is likely to prevent the career field from completing important mission objectives. The same is true with respect to the marginal cost of a surplus. A small surplus may be harmless, but a large surplus will compel the Air Force to pay officers that are not really needed. Furthermore, it is likely that, in order to stay below the congressionally mandated end strengths, the Air Force may have to pay officers to leave the Air Force down the road. This behavior can be modeled as a step function, like that shown in Figure 3.

Let $shortpen_{cu}$ be the per-unit cost of a shortage in AFSC c when the current magnitude of the shortage is at level u and let $shortlim_{cu}$ be the capacity of the uth shortage level for AFSC c. For example, for an AFSC c, with shortage costs described by the step function in Figure 3, $shortpen_{c2} = 10$ and $shortlim_{c2} = 0.10 * goal_c$. Define $surppen_{co}$ and $surplim_{co}$ in a similar manner.
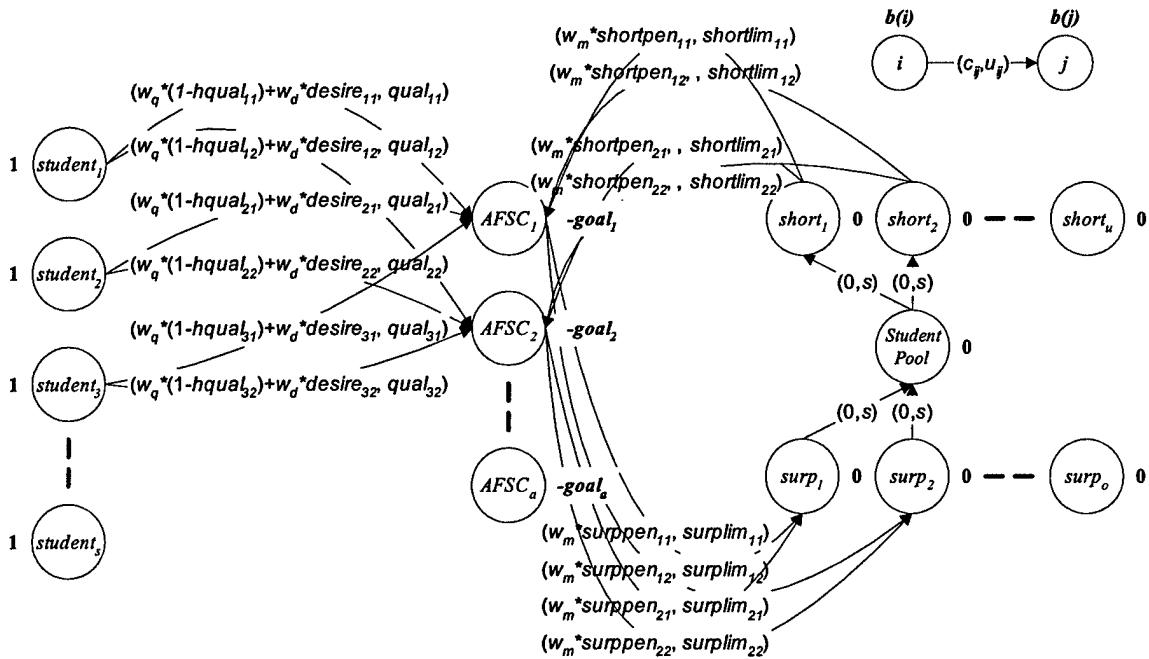
Figure 4. Network with students, AFSCs, and numerous shortage and surplus nodes

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Consider the network, depicted in Figure 4, in which each shortage node has been replaced by u shortage nodes and each surplus node has been replaced by o surplus nodes. Note that flow from each AFSC can be routed through any of o arcs in order to reach a surplus node. That is, each unit of flow can incur one of o unique costs. Suppose that $surppen_{c1} < surppen_{c2} < ... < surppen_{co}$ for some AFSC c. When a surplus occurs in AFSC c, flow will be routed from AFSC node c to at least one of the surplus nodes. In minimizing the total cost of the flow through the network, each unit of flow will select the cheapest available arc. The first unit of surplus will select the arc that flows into the node $surp_1$. Each additional unit of flow up to $surplim_{c1}$ will also select this arc and be charged $surppen_{c1}$. Once the size of the surplus reaches $surplim_{c1}$, the arc connecting AFSC c and $surp_1$ will become saturated. At this point, the arc will no longer be available and each additional unit of flow will have to choose another more expensive path. By adding multiple shortage and surplus arcs of finite capacity for each AFSC, the costs represented in the network flow model are more realistic.

As a final modification, consider the network shown in Figure 5, in which the demands of each AFSC node are consolidated into one demand at a sink node.
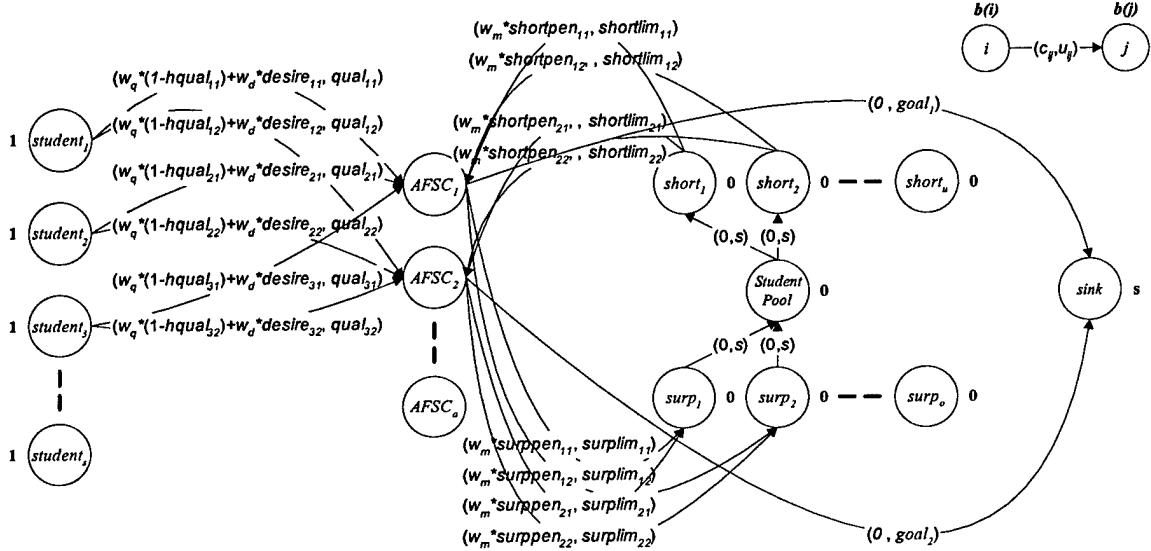
Figure 5.   Network with sink node added to consolidate AFSC demands

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In Figure 5 each AFSC is connected to the sink with an arc whose capacity is equal to the accession goal for that AFSC and whose cost is zero. This network formulation is equivalent to the previous network, which did not have a sink node, but proves more useful in efficiently solving this problem because it has only one demand node versus the thirty eight demand nodes in the previous network.

E.   SOLVING THE MODEL

Network flow problems are linear programs and therefore can be solved fairly easily using linear programming methods. However, network flow problems can often be solved more efficiently using special-purpose algorithms. These algorithms can be implemented in any specific programming language and offer the added benefit of eliminating the need to obtain a commercial solver. The approach used here is to modify an existing polynomial-time algorithm[8], by adding a few practical improvements, and use this algorithm to solve the target setting problem.

The successive shortest path algorithm[9] is a special-purpose algorithm that requires pseudo-polynomial time to solve the general minimum cost flow problem. The largest supply in this network is one, however. So, in this case, the algorithm is strongly polynomial. As suggested by its name, the shortest path problem shows up as a subproblem in the successive shortest path algorithm. Negative costs do not appear in this network, but directed cycles do. Therefore, Dijkstra's algorithm[10] is a good label-setting algorithm to choose. These two algorithms are efficient in their present form. However, the structure of this particular network enables a few practical improvements.

As stated, Dijkstra's algorithm determines the shortest path distances from a given node to all other nodes in the network. The successive shortest path algorithm, however, only calls for a shortest path from k to l. Therefore, a shortest path from k to l is sufficient, and the algorithm can be terminated once this path has been determined.

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[8] The widely-accepted standard for a "good" algorithm is one whose worst-case complexity is bounded by a polynomial function of the problem's parameters. This is discussed in *Network Flows*, by Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin (Upper Saddle River: Prentice Hall, 1993), 60.

[9]"Successive Shortest Path Algorithm," in *Network Flows*, by Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin (Upper Saddle River: Prentice Hall, 1993), 320-24.

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In the successive shortest path algorithm, selecting the excess and deficit nodes may require every node in the network to be scanned. Determining the maximum quantity of supply that can be shipped from the excess node to the deficit node requires every arc in the shortest path to be considered. In this network, the students are supply nodes, with precisely one unit of supply, and there is only one demand node: the *sink*. Suppose that an arbitrary student ordering is established prior to executing the algorithm. Then, it is sufficient to designate a new student $s \in S$ as the excess node and ship one unit of supply from the student node to the *sink* at each intermediate step.

The modified successive shortest path algorithm is stated below in pseudocode that a reader with a casual familiarity with computer programming should comprehend[11].

algorithm *modified successive shortest path*

begin

> $x := 0$ and $\pi := 0$;
>
> initialize $S := \{student_1, ..., student_s\}$;
>
> **while** $S \neq \varnothing$
>
> **begin**
>
> > select and remove a node $s \in S$;
> >
> > determine shortest path distance $d(sink)$ from node s to
> >
> > > node *sink* with respect to the reduced costs c_{ij}^{π};
> >
> > let P denote a shortest path from node s to node *sink*;
> >
> > update $\pi(i) := \pi(i) - d(i) + d(sink)$ for each permanently
> >
> > > labeled node $i \in N$
> >
> > augment 1 unit of flow along the path P;
> >
> > update x, $G(x)$, and the reduced costs;
>
> **end**

end

Figure 6. Modified successive shortest path algorithm

10 "Dijkstra's Algorithm," in *Network Flows*, by Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin (Upper Saddle River: Prentice Hall, 1993), 108-13.

11 The node potential $\pi(i)$ is the linear programming dual variable corresponding to the mass balance constraint of node i. The distance label $d(i)$ is the shortest path distance from the source node to node i produced by the shortest path subproblem. For an in depth discussion, see *Network Flows*, by Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin (Upper Saddle River: Prentice Hall, 1993)

III. THE GRAPHICAL USER INTERFACE

In the previous section, the target setting problem was represented as a network flow problem and a special-purpose algorithm was introduced to efficiently solve this problem. In this section, a user interface is presented that will enable individuals to manipulate the model, perform sensitivity analysis, and select the most favorable targets from a wide range of alternatives. The user interface presented here is intended to be suitable for individuals with no technical background.

A. OVERVIEW

Both the model and the user interface are implemented in the Java programming language. This provides decision makers with a free, fully functional tool to assist them in setting sensible accession targets for the three Air Force commissioning sources. The user interface features a menu that allows decision makers to select from among a series of views. Each view enables decision makers to see the effects of the costs and the weights that they have established. By adjusting the deviational costs of each AFSC, which are presented in an editable spreadsheet, the user defines the AFSC fill priority. By manipulating the slider bars located below the menu, the decision maker controls the relative importance of each of the three objectives: meeting manpower needs, meeting quality needs, and meeting personal preferences. Using TALENT, decision makers incrementally adjust deviational costs and objective weights to influence the model's behavior and converge towards the most favorable targets, with respect to their own personal optimality criteria.

B. OBJECTIVE WEIGHTS

In multiobjective programming, it is often difficult to devise a clear, quantitative way to compare feasible solutions. That is, solutions may be evaluated quite differently by different decision makers. In models with two objectives, tradeoffs can be easily visualized by constructing efficient frontier curves. However, these curves can be confusing in more than two dimensions. Slider bars, located below the menu, are used by

the decision maker to specify the relative weight assigned to each objective. It is difficult to select the "best" weights and the slider bars allow decision makers to experiment with many different weighting schemes. By using these slider bars, they can guess initial weights, see how the model responds to these weights, and then adjust the weights until they converge on a solution that matches their personal concept of optimality. The weights are normalized so that when the values specified for the objectives are equivalent, the costs associated with each objective will be of approximately the same magnitude. In Figure 7, a weight of 80 is assigned to the manpower needs objective, a weight of 40 is assigned to the quality needs objective, and a weight of 20 is assigned to the personal preferences objective. The results of this weighting scheme will be displayed once the model is executed by clicking the "Execute Model" menu option.
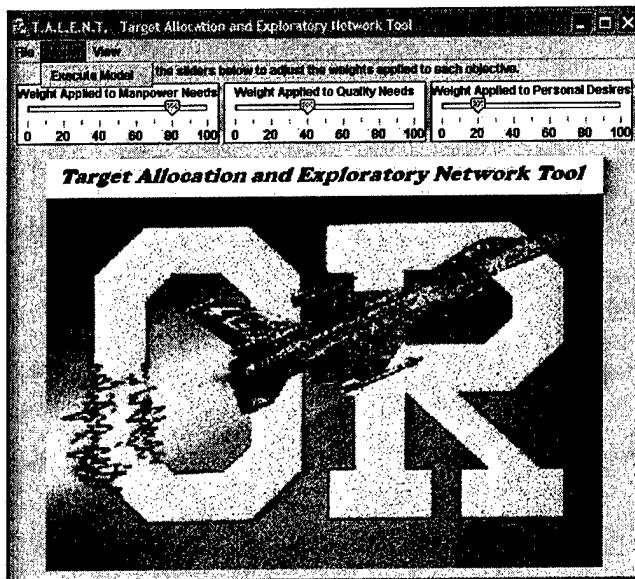
Figure 7.   Example in which objective weights have been set[12]

C.   SHORTAGE AND SURPLUS COSTS

Manpower needs are an important consideration in setting accession targets for the commissioning sources. The manpower needs objective appears in the network flow model as the arc costs assigned to the shortage and surplus arcs. When weight is assigned to the manpower needs objective, these costs determine the AFSC fill priority. That is, when two AFSCs are competing for a limited number of qualified students the

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[12] The graphic shown was designed by the Operations Research faculty at the USAF Academy.

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shortage costs determine how the students will be split between the two AFSCs. Similarly, when there are excess students who cannot fill the "hard-to-fill" specialties, these costs determine which of the "easy-to-fill" specialties will accept the surplus. Therefore, the cost table plays a crucial role in creating model transparency and flexibility. By allowing users to adjust deviational costs, in response to solutions they have seen, they can converge to a solution that satisfies their preferred fill priority.
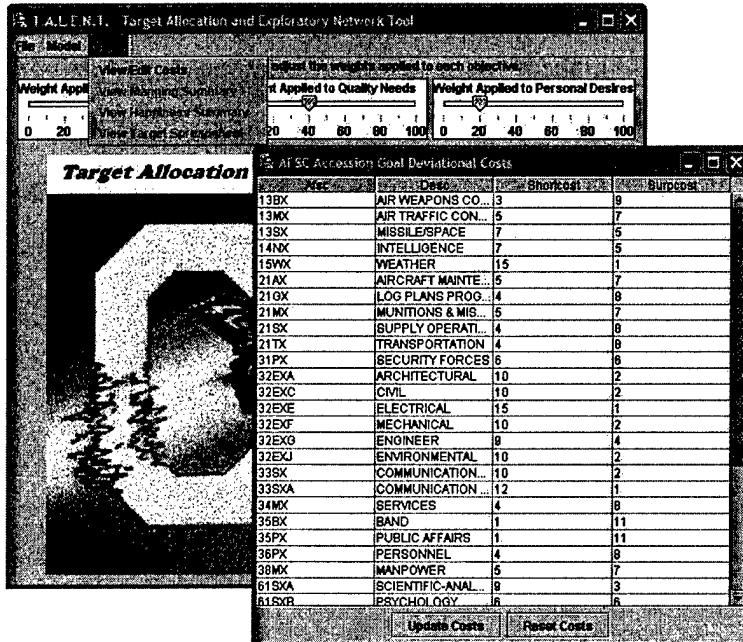
Figure 8. Sample cost table used to modify deviational costs

These costs are set, by the decision maker, using the table shown in Figure 8. This table, generated by selecting the "View/Edit Costs" menu option, lists every AFSC, along with a brief description of the AFSC, and its associated per-unit shortage and surplus costs. The initial costs, displayed when the table is first viewed, reflect the costs that are specified alongside the overall accession goals in the AFSC data file. Note that the costs listed in this table are constants, but the shortage and surplus costs are modeled as piecewise linear functions. The values entered in this table refer to the base line. This means that these costs specify a fill-priority for AFSCs when existing AFSC shortages/surpluses are of a similar magnitude.

This table offers the basic functionality common to most spreadsheets and desired changes are stored in the model by clicking the "Update Costs" button located at the

bottom of the frame. If users wishes to undo changes, then click the "Reset Costs" button and the initial costs, specified by the AFSC input file, are restored. If so desired, data contained in this table can be copied and pasted into other applications as well.

D.   VISUALIZING RESULTS

The strength of the user interface lies in its ability to provide the user with a visual display of the results. This section discusses the many valuable charts, produced by this interface, used by decision makers to assess solutions in terms of the three objectives.

1.   Manpower and Quality Needs Summary
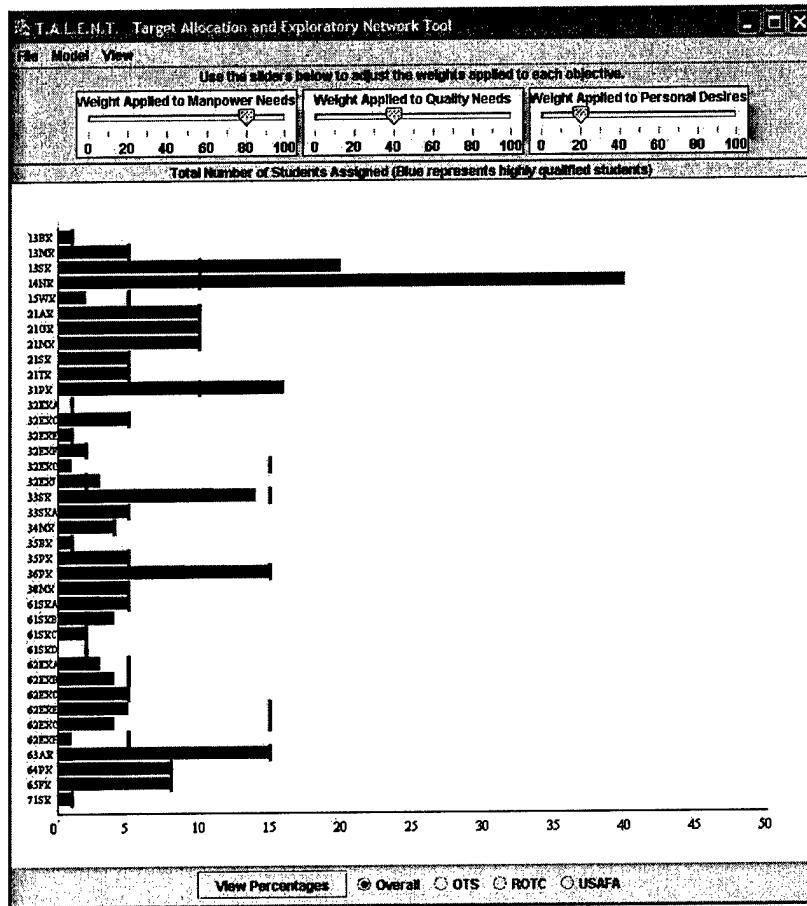
Figure 9.   Numerical manning summary for 250 student problem

Figure 9 displays a bar chart that is generated by the user interface to assess a particular solution in terms of both manpower and quality needs. This chart lists the non-rated line AFSCs on the vertical axis and the number of students that the targets represent

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on the horizontal axis. The total students that are expected to be classified into each AFSC are represented by the length of the gray bars corresponding to each AFSC. The highly qualified students for a particular AFSC are represented by blue bars. Corresponding to each AFSC is a red line used to indicate the overall accession goal of that AFSC[13]. Thus, an ideal solution would feature blue bars that reach the red line corresponding to each AFSC. This is unlikely to happen, and so the decision maker hopes to generate a picture as close to this as possible. Naturally, the decision maker assumes the responsibility of defining "close".
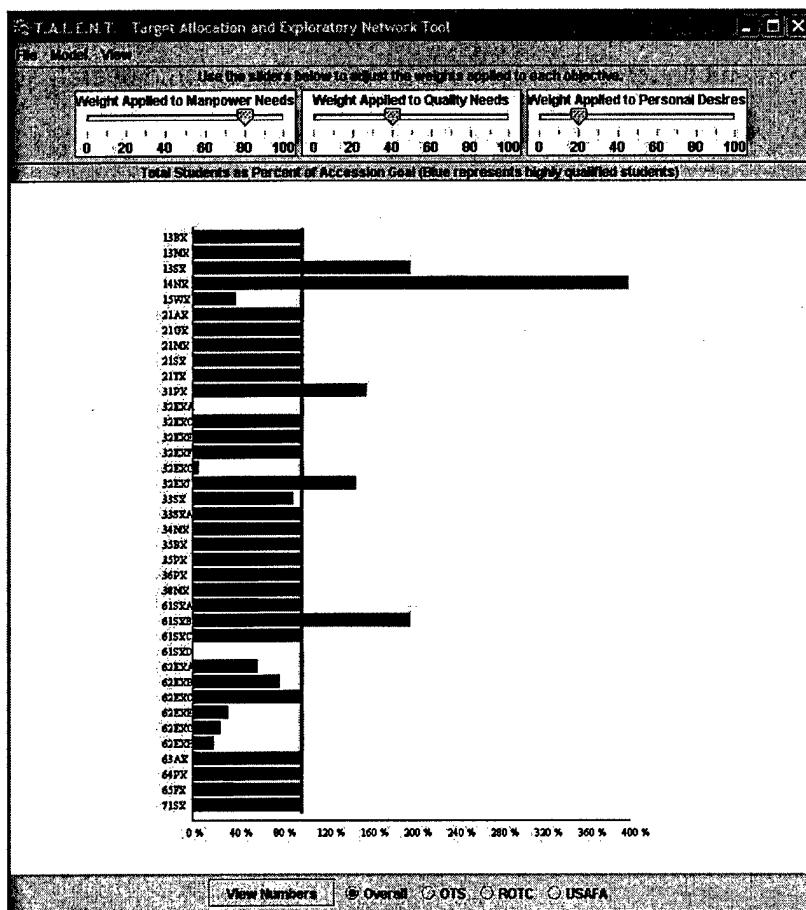
Figure 10.   Example manning summary in percentage terms

The user interface also displays a manpower summary in percentage terms, like that shown in Figure 10. This summary is generated by clicking the "View Percentages"

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13 If this is printed in black and white, the dark bars represent the total students that are expected to be classified into each AFSC, the light bars represent highly qualified students, and the dark line indicates overall AFSC accession goals.

button located below the chart. This display is useful for quickly identifying deviations from overall AFSC accession goals. As before, the AFSCs are listed on the vertical axis and, in this chart, the percentage of the accession goal represented by the targets is displayed on the horizontal axis. The red line indicates the 100% desired fill level for each AFSC.

By selecting the appropriate bubble, located below the chart and to the right of the "View Numbers" button, decision makers can determine within which source the students in each AFSC are produced (i.e. the overall OTS, ROTC, and USAFA targets). Once again, this is available in either empirical or percentage terms. Figure 11 displays one such chart, in percentage terms, to represent the percentage of the overall accession goals that are filled by ROTC students.
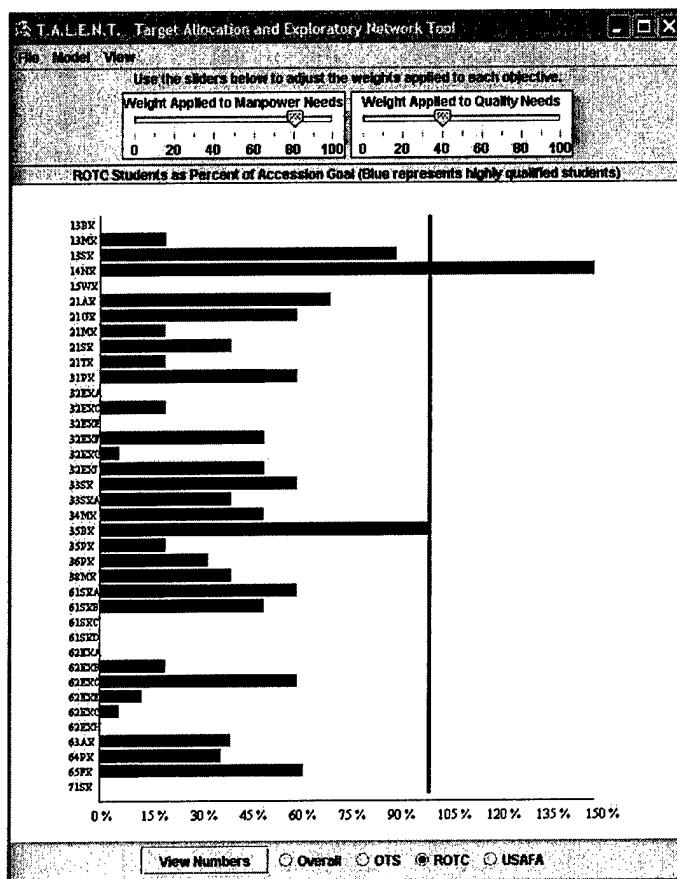
Figure 11. Sample ROTC manning summary in percentage terms

Notice that the contribution of ROTC towards meeting accession goals varies, as expected, by AFSC. This demonstrates that ROTC has both strengths and weaknesses that are captured in this model. In the example represented by Figure 11, ROTC has a good supply of weather officers, but cannot provide any electrical engineers.

The manpower and quality needs summary charts provide decision makers to analyze solutions in terms of both the manpower needs and the quality needs of the non-rated line officer specialties. By switching between the empirical data and percentages, the user gains an understanding of the effect of the deviational costs and the weights in terms of meeting these two objectives. Viewing individual accession production from each commissioning source increases the transparency of individual strengths and weaknesses.

2. Personal Satisfaction Summary

Both the manpower needs and the quality needs of the AFSCs are weighted, by the decision maker, versus the personal preferences of the students. Clicking the "View Satisfaction Summary" option from the view menu generates a bar graph that displays the satisfaction of the students with the selected targets. An example chart is shown in Figure 12.
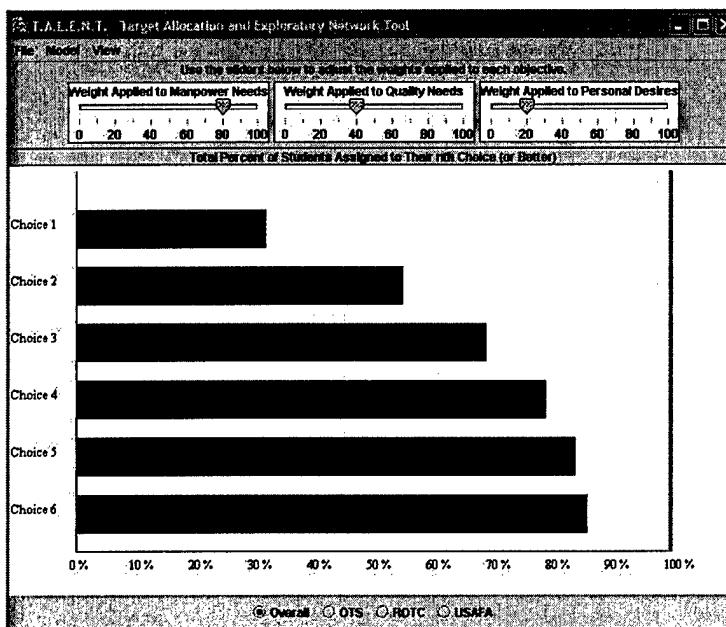
Figure 12.   Example satisfaction summary

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Students submit an ordered list of the six AFSCs into which they most desire to be classified. The vertical axis is labeled with six choices. The horizontal axis is labeled with percentages. The blue bar next to each choice represents the percentage of students who were classified into an AFSC corresponding to a choice at least as desirable as the indicated choice. For example, the bar associated with choice three indicates the percentage of students who were classified into one of their top three choices. As before, the red vertical line emphasizes the one hundred percent goal, which may or may not be attainable depending on the particular student preferences.

As with the manpower summary, decision makers view the ability of a particular solution to satisfy the preferences of students within the three commissioning sources by selecting the proper bubble, which is located at the bottom of the frame. The ability of this example solution to satisfy OTS student preferences is shown in Figure 13.
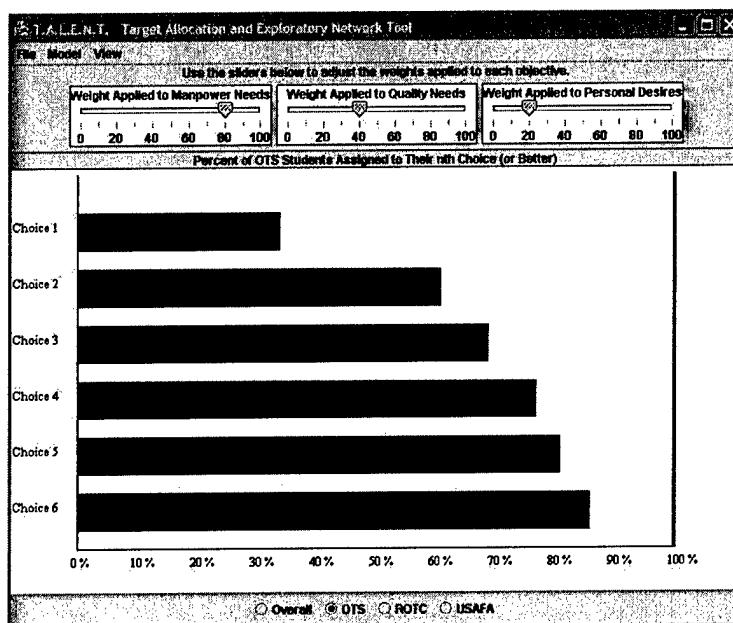
Figure 13.   Example OTS satisfaction summary

3.   Targets Summary

The targets corresponding to a particular solution are displayed and can be extracted by selecting the "View Target Spreadsheet" option from the "View" menu. As shown in Figure 14 on the next page, the overall accession targets are generated in tabular form with AFSCs listed in the first column and the corresponding targets for each cycle

listed in the adjacent columns. OTS, ROTC, and USAFA targets are displayed in a similar format. Since the data is presented in the form of a spreadsheet, this information can be cut and pasted into other applications and sent off to the commissioning sources to be used for classification.

Air Force Sp.	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8
13BX	1	0	0	0	0	0	0	0
13MX	2	1	0	0	0	0	1	1
13SX	5	3	0	2	2	3	3	2
14NX	11	6	4	4	4	4	2	5
15WX	1	1	0	0	0	0	0	0
21AX	2	1	3	2	0	0	2	0
21GX	1	1	2	2	1	0	2	1
21MX	4	1	0	2	1	2	0	0
21SX	4	0	0	0	0	0	0	1
21TX	3	0	0	0	2	0	0	0
31PX	6	2	1	4	1	0	1	1
32EXA	0	0	0	0	0	0	0	0
32EXC	2	0	0	1	0	0	0	2
32EXE	1	0	0	0	0	0	0	0
32EXF	0	0	0	0	0	1	1	0
32EXG	1	0	0	0	0	0	0	0
32EXJ	3	0	0	0	0	0	0	0
33SX	4	0	3	0	2	3	1	1
33SXA	0	0	1	0	1	2	0	1
34MX	1	0	1	0	2	0	0	0
35BX	0	0	0	0	0	0	0	1
35PX	2	0	0	0	0	1	2	0
36PX	3	1	1	3	1	1	4	1
38MX	2	0	1	1	0	0	1	0
61SXA	3	0	0	1	0	0	1	0
61SXB	3	0	0	1	0	0	0	0

Figure 14.   Example targets spreadsheet

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IV. INPUT DATA AND COMPUTATIONAL RESULTS

A. INPUT DATA

1. Identifying Qualified and Highly Qualified Students

Several Air Force specialty codes require officers to possess specific degrees. While many AFSCs do not have degree requirements, they may prefer a certain officer over others, based on the officer's academic background. Information, like that shown in Table 1, is determined for every non-rated AFSC. These descriptive requirements and desirable qualifications are used to create a zero/one mapping between Air Force degree codes and non-rated AFSCs. This mapping, in turn, determines the value of $qual_{sc}$ and $hqual_{sc}$ for every student/AFSC pair (s,c).

| AFSC	MANDATORY DEGREE	DESIRABLE QUALIFICATIONS/DEGREE
14NX (INTELLIGENCE)	NONE	Information Sciences, Foreign Area Studies, Foreign Language
15WX (WEATHER)	NONE [However, must have sufficient coursework in Meteorological Sciences]	Meteorology, Atmospheric Science, Math
62EXE (ELECTRICAL ENGINEER)	Electrical or Electronics Engr	[Masters in same]
31PX (SECURITY FORCES)	NONE	Sociology, Criminology, Criminal Justice, Foreign Language
34MX (SERVICES)	NONE	Hospitality, Hotel/Restaraunt Mgmt, Finance
35BX (BAND)	NONE [Audition Required]	Music, Music Ed, or related field
35PX (PUBLIC AFFAIRS)	NONE	Mass or public Comm, Journalism, Public Relations, Advertising

Table 1   Sample degree requirements and desirable qualifications for seven AFSCs

As indicated by Table 1, the Intelligence, Security Forces, Services, and Public Affairs AFSCs have no degree requirements. While the Weather and Band AFSCs have no specific degree requirements, officers do have to meet other entry requirements. Note that the Electrical Engineer AFSC has an Electrical or Electronics Engineering degree requirement. Sample desirable qualifications are also shown in Table 1. In this case, a student with a degree in meteorology is highly qualified for the Weather AFSC, while a student with a foreign language background is highly qualified for the Intelligence AFSC.

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2. AFSC Data

Accession goals and initial shortage/surplus costs must be input into the model. The accession goals, based on long-term manpower needs, and initial shortage/surplus costs, based on the ability of each AFSC to withstand a shortage or a surplus, are determined by the Air Force Personnel Operations agency. Clearly, the deviational costs can be, and likely will have to be, adjusted within the target setting model. So, it is not necessary to set these costs ahead of time. However, setting good initial costs provides a good starting point for the analysis. Sample AFSC data is shown in Table 2 below.

AFSC	Description	Accession Goal	Surplus Cost	Shortage Cost
13SX	MISSILE/SPACE	216	3	7
14NX	INTELLIGENCE	216	4	6
15WX	WEATHER	16	2	8
31PX	SECURITY FORCES	72	3	7
32EXE	ELECTRICAL ENGINEER	2	2	8
35PX	PUBLIC AFFAIRS	24	6	4
63AX	ACQUISITIONS	204	4	6
71SX	OSI	56	5	5

Table 2   Sample AFSC data used in classifying 2022 students

In Table 2, each AFSC is listed in the first column. Adjacent to it, in the second column, is a description of the AFSC. The annual accession goal, calculated by AFPOA, is listed in the third column. A solution in which the sum of the targets for a given AFSC does not equal its accession goal is penalized, based on the direction of the deviation, by one of the two costs to the right of this value. Recall that surplus and shortage costs are modeled as piecewise linear cost functions. The surplus and shortage costs listed here define the base level cost. That is to say, these costs are charged for the first surplus/shortage level. Further deviations from the accession goal are penalized more than this. The electrical engineering specialties and the weather specialty define the first critical need tier. For this reason, these AFSCs are assigned large shortage costs and small surplus costs. The public affairs specialty, on the other hand, is historically

overmanned. Accordingly, this AFSC is assigned a large surplus cost and a relatively small shortage cost.

To ensure feasibility and proper model behavior, the sum of the accession goals listed here must exactly equal the total number of students being considered in the model. If this is not the case, the model implementation will print a warning message.

3. Student Data

Student Name	Source of Commissioning	Month of Graduation	Degree Code	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice	6th Choice
STUDENT1	OTS	JUL	3AYY	61SXB	14NX	34MX	21AX	36PX	35PX
STUDENT2	OTS	DEC	0IYY	33SXC	36PX	64PX	21SX	21GX	38MX
STUDENT3	OTS	JAN	4HYY	32EXC	62EXG	63AX	32EXG	14NX	31PX
STUDENT4	OTS	MAY	5YYY	64PX	63AX	36PX	33SXC	14NX	NONE
STUDENT5	OTS	DEC	8DCY	14NX	13SX	21MX	36PX	35PX	38MX
STUDENT6	OTS	NOV	4BYY	62EXA	62EXB	61SXD	62EXE	62EXH	21TX
STUDENT7	ROTC	NOV	2DYD	14NX	35PX	36PX	38MX	NONE	NONE
STUDENT8	ROTC	APR	1AAY	13BXK	14NX	64PX	63AX	65WX	21AX
STUDENT9	ROTC	APR	0CYY	33SXC	33SXA	62EXC	63AX	14NX	NONE
STUDENT10	ROTC	OCT	9HAY	31PX	14NX	65FX	21TX	36PX	21SX
STUDENT11	ROTC	JUL	4IYY	62EXE	32EXE	13MX	NONE	NONE	NONE
STUDENT12	ROTC	DEC	9EYY	14NX	35PX	13SX	36PX	21SX	21TX
STUDENT13	USAFA	MAY	4MYY	64PX	14NX	62EXG	21GX	NONE	NONE
STUDENT14	USAFA	MAY	9HAY	NONE	31PX	61SXB	14NX	36PX	65FX
STUDENT15	USAFA	MAY	9FYY	13SX	21AX	13BXK	21MX	14NX	13MX

Table 3   Sample data for 15 students

Every student belongs to a commissioning source and a classification cycle. Membership to a given classification cycle is determined by a student's month of graduation. This data needs to be passed into the model to enable target allocation. Student degree codes are needed to determine for which AFSCs students are qualified and highly qualified. Prior to classification, each student submits an ordered list of their AFSC preferences. It is important to note that all of this data may not exist for all students to be classified in the coming year and, hence, some data may have to be predicted based on historical data.[14]. A sample data set consisting of fifteen students and their necessary information is shown in Table 3. In this data set, there are five students

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[14] The Officer Training School course produces officers in just twelve weeks, and students are often accepted shortly before classes commence. This means that the students within a particular OTS cycle may not be known when it is time to classify students.

each from OTS and ROTC, and three USAFA students. Using this data, the model is able to assess the accession capability of each source.

B.   RESULTS

The Privacy Act precluded the Air Force Personnel Center from releasing student data from 2002. However, a cross-sectional sample of 2022 students, 1666 ROTC students and 356 USAFA students, was provided for analysis. Suitable OTS student data was not available at the time of this research.

Currently, commissioning sources are assigned "fair-share" targets, and there is no guarantee that the sources will be able to establish better targets when they meet at the NRLOAC. To compare the effects of targets assigned using this model with the effects of using "fair-share" targets, the students were divided into their respective commissioning sources and cycles and each group was assigned "fair-share" targets representative of the accession goals displayed in Table 1. ROTC students were divided into two cycles, as is traditionally done. The main cycle consisted of 1499 students, with the off cycle containing the remaining 167 students. All 356 USAFA students were grouped into one cycle, as is customary. Realize that the accession goals were chosen, on purpose, to be attainable in the case that the sources are allocated targets in the joint model. This is important because, in the case that the Air Force can attain the goals set by AFPOA, it would be undesirable to not meet these goals, which represent the optimal classification strategy in terms of meeting the long term manpower needs of the Air Force.

One would expect that, with only three groups of students, 74% of which belong to the main ROTC cycle, it should be possible to meet the accession goals. After all, the real problem that the Air Force faces each year consists of thirteen groups of students[15]. However, this was not the case. Clearly, even when a small number of groups are involved, "fair-share" targets will cause AFSC goals to be needlessly missed.

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15 There are eight OTS classification cycles, corresponding to the eight classes offered each year. There are two OTS cycles: a main cycle that includes spring and summer graduates, and an off-cycle that includes fall and winter graduates. USAFA conducts only one classification cycle to include all of its graduating students.

Figure 15 compares the fill levels of each of the critical need AFSCs (i.e. technical career fields) when fair-share targets are used with the levels attainable when targets are allocated in using this model. The AFSCs are listed on the horizontal axis and the fill level, in percentage terms, is shown on the vertical axis. Note that the 32EXA AFSC, corresponding to the electrical developmental engineer specialty only achieves a little more than 65% of the fill that could have been realized if sensible targets were assigned. The 33SXA (Electrical Communications and Information) and the 32EXF (Mechanical Engineering) AFSCs are also well short of their accession goals.
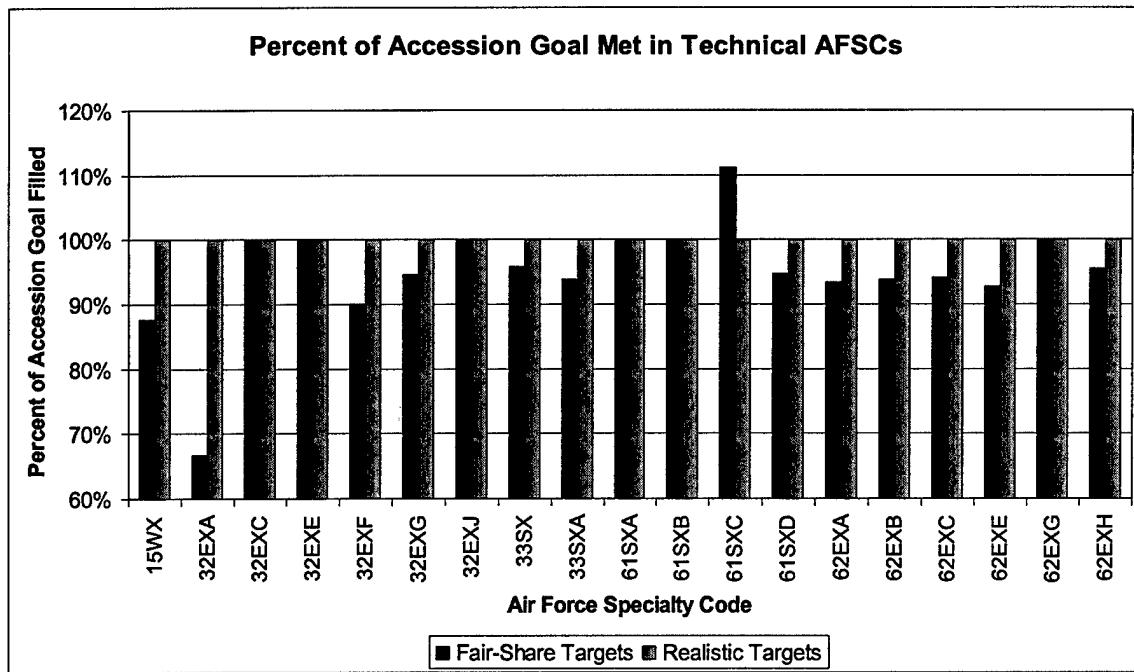

Figure 15. Technical AFSC resulting fill levels

Whenever shortages occur in the "hard-to-fill" AFSCs, surpluses result in the non-technical AFSCs. In the case where targets are allocated sensibly, there are no shortages and no surpluses. However, as shown in Figure 16, surpluses result in several AFSCs when "fair-share" targets are assigned. In this situation, manpower needs were assigned the largest weight, by far, but personal preferences were used to break ties. In this graph, it is evident that a few AFSCs receive the entire influx of students, whenever students cannot be placed into the "hard-to-fill" specialties. The 35PX (public affairs) AFSC received, by far, the largest flow of surplus students when "fair-share" targets were assigned. This is because 35PX is a very popular AFSC. In meeting the AFSC goals,

each source placed surplus students into this AFSC. Since they had no way of knowing what the other sources were doing with their students, this seemed like a reasonable thing to do. This is a classic case of the contributions of local optima towards a globally suboptimal solution.
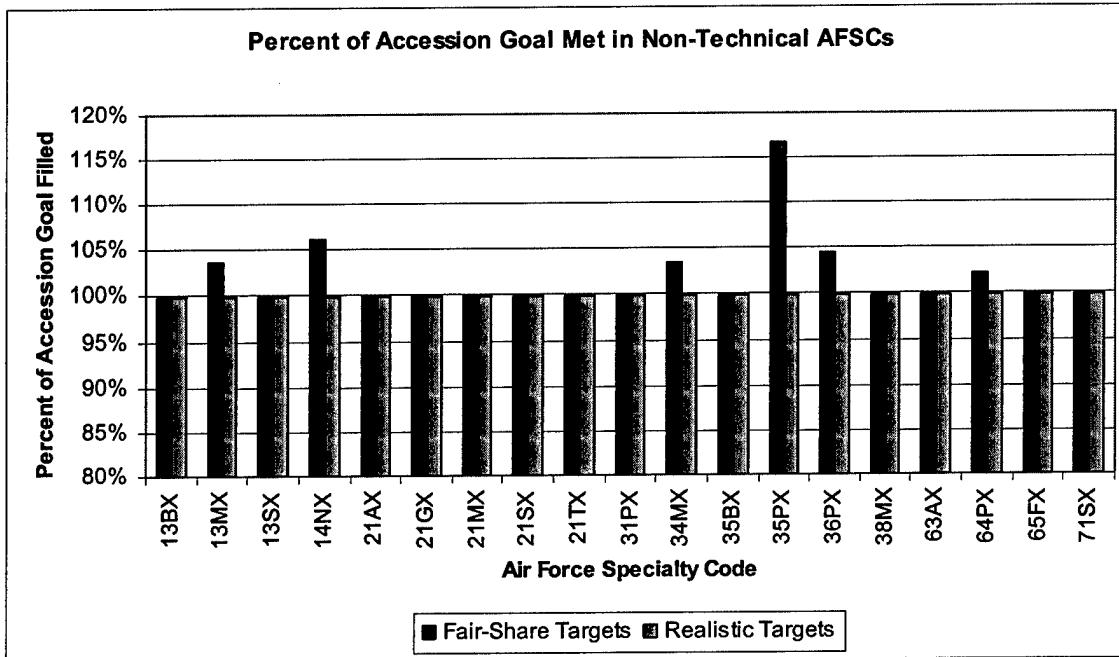

Figure 16. Non-technical AFSC resulting fill levels

It's natural to imagine that the students would be more satisfied with their assignments in the fair-share case. That is to say, students were not forced into technical fields in the fair-share case and, instead, were placed into popular specialties, like public affairs. This, however, is not the case. In the case of joint target setting, the student desires, in this case, within all three sources are considered. This means that students, who might have been unhappy with their assignments resulting from fair-share targets, are able to trade. For example, if a student from ROTC prefers the space and missile career fields and ROTC is out of slots, but USAFA has an extra slot, the ROTC student can communicate his needs and ROTC will get the extra target. This enables personal preferences to be better satisfied as well. This is demonstrated in Figure 17 on the next page, which displays the level of personal desires satisfied. This chart displays the percentage of students who were assigned their first choice, one of their top two choices,

one of their top three choices, etc. Although a higher percentage of students were given their first choice, the student needs were generally not met as well in the case of fair-share targets. It may appear as though this model does not meet student desires very well. In fact, giving only 85% of the students on of their top six choices is far from spectacular. However, this is not so much a factor of the model as it is a factor of students not inputting six preferences. Most USAFA students submitted six preferences. As a result, USAFA students were actually assigned one of their top six choices 94% of the time. On the other hand, the ROTC students, many of whom only submitted two AFSC choices, were only placed into one of their top choices 80% of the time. Regardless, it should be clear that this model performs at meeting the classification objectives than the "fair-share" strategy. Clearly, the "fair-share" strategy is naive. However, there is no guarantee and, in fact, it is unlikely that the NRLOAC will succeed in setting targets that are any better than the fair-share targets. For this reason, a target setting model would be a very beneficial addition to the personnel arsenal.
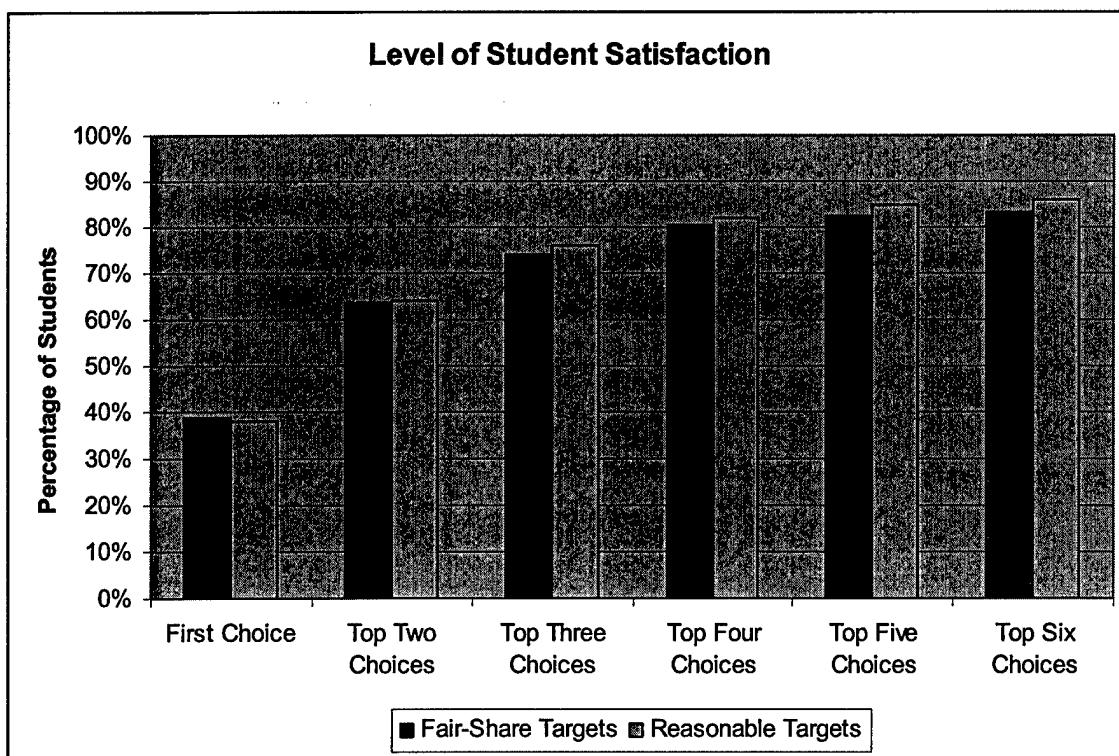

Figure 17.   Resulting Student Satisfaction

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

There is currently a significant mismatch between annual accession goals, representative of long term Air Force needs, and the near term accession capability of each commissioning source. The Non-Rated Line Officer Accession Conference represents the current course of action through which this problem is addressed. At this conference, the accession capabilities of the commissioning sources are not made suitably visible and, when students cannot be placed into "hard-to-fill" AFSCs and a shortage results, it is unclear where the additional students should be placed. As a result, attendees are poorly equipped to resolve the problem. This prevents highly qualified students from being identified and causes personal desires to be ignored.

If the target setting process is left as-is, classification results will continue to be unsatisfactory. The non-rated AFSC accession goals will not be adequately met, resulting in unnecessarily large long-term shortages in critical need technical career fields and increased surpluses in historically overmanned career fields. Non-rated line AFSCs will not be filled with the most qualified officers available, resulting in inferior mission effectiveness. Additionally, officers will be forced to enter undesirable career fields, which can impair job performance and harm retention, further aggravating shortages in critical career fields.

The Target Allocation and Exploratory Network Tool (TALENT) enables personnel managers to determine targets that exploit individual accession capabilities – that is, identifies highly qualified students and considers student desires in setting sensible targets, representative of overall accession goals, for each commissioning source and cycle. The underlying optimization model incorporates piecewise linear shortage and surplus penalties to better represent the true effects of deviating from accession goals. Because of its special structure, the underlying model is solved very quickly, using a specialized network algorithm. With a user-friendly interface, TALENT enables individuals to perform graphical sensitivity analysis and, in doing so, select sensible

targets from a wide range of alternatives. It is implemented completely in Java[16], which facilitates rapid deployment and means that no commercial software is required[17]. TALENT bridges the existing gap between long-term needs and near-term capabilities, providing the Air Force with a valuable weapon in the war for talent.

B. RECOMMENDATIONS

The tool presented in this thesis will not solve all of the manpower problems facing the Air Force. For example, this model does not involve itself with rated officers and professionals, such as doctors, lawyers, and chaplains. Nor does it offer instruction in terms of how to recruit and retain the kinds of officers demanded by the non-rated line AFSCs. The Air Force has trouble attracting and retaining technical officers. Until this problem is resolved, shortages and surpluses will exist. This tool does, however enable the Air Force to best utilize the human resources that it does have, so as to minimize the effects of these inevitable shortages and surpluses. Specifically, TALENT improves the transparency of the process and provides personnelists with a way to quantify priorities and perform rapid experimentation. By integrating this model within the current classification framework the Air Force will better utilize its human resources and improve its ability to meet long-term non-rated line officer AFSC manpower needs. The USAF must grow its own talent. The ability of the Air Force to do this will determine its long-term health. This model helps decision makers to plant seeds in the right places and enables the Air Force to make a powerful and lasting impression on its employees: the Air Force cares about its people and values their contributions.

C. FURTHER RESEARCH

In this model, students can only be classified into AFSCs for which they are qualified – that is, they meet the AFSC degree requirements. This assignment costs a certain amount that is based on student desires and desirable qualifications. As previously mentioned, the Air Force has tremendous difficulty attracting officers capable

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[16] For an electronic copy of the code, visit http://diana.gl.nps.navy.mil/~dholwell/Java_Sickorez.htm.

[17] The Java 2 Standard Edition Version 1.4.2 runtime environment can be downloaded for free at the Sun website – http://java.sun.com/j2se/1.4.2/download.html.

of filling technical needs, especially when it comes to weathermen and electrical engineers. This means that, in a given year, a large number of newly commissioned officers possess degrees that the Air Force does not, in fact, need. Both the Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS) provide one year graduate programs in technical areas, such as meteorology and electrical engineering. This provides another option for the Air Force. Rather than classifying a student into an AFSC that is already filled to a suitable level, the student can be identified as a graduate school candidate in a field that the Air Force needs. It may be that sending a student to pursue a one year masters in a technical field is an economically superior decision when compared to classifying the student into an already overmanned career field. This is captured in the network flow model by adding an arc from each student to those AFSCs for which they are not qualified and adding a cost reflective of the cost of sending a student to graduate school. This setup enables the Air Force to avoid accessing officers that it doesn't really need, and instead enables the Air Force to develop the student into the type of officer that the Air Force does need. Determining appropriate arc costs, both for the shortage/surplus arcs and the student/AFSC arcs, in order to realistically capture this tradeoff is a reasonable next step for this model.

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